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BIOMORPHIC NETWORKS FOR ATR AND HIGHER-LEVEL PROCESSING

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During the period of this report we carried out several key numerical simulation to further probe the behavior of the parametrically coupled logistic map (PCLM) network. The result of these experiments and those from earlier work are given next in the form of list of key properties or mechanism operating in the PCLM net.:

- Ability to accept and classify dynamical (spatio-temporal) inputs in addition to static inputs.

- Classification is via convergence to a **compact dynamic attractor**(c.d.a.) through a rapid cascade of **state-determined bifurcations** at critical points, i.e., input specific attractors are arrived at via a rapid cascade of state-determined bifurcations.

- Convergence to a c.d.a. is independent of initial state of the network which is biomorphic.

- Very large number of coexisting attractors that are accessed by extrinsic inputs.

- Attractors can combine all three orbit types: fixed-point, periodic, and chaotic/intermittent.

- Convergence to a compact attractor constitutes a data compression operation analogous to the vast data compression capability of the brain.

- Convergence to isolated clusters of activity, representing the compact attractor is reminiscent to the "hot spots" seen in fMRI of brain activity.

- Compact dynamic attractors were observed only when the choice of network parameters reflected general known and plausible attributes of cortical organization. These included:

  - Dominance of local connectivity.

  - Self-connections to reflect an inherent property of a netlet.

  - Gradual handing over of control over network dynamics (evolution in time) from extrinsic to intrinsic control [W. J. Freeman, (1995), also suggested in a different context by Stan Franklin, (1995)].

  - Nonlinear coupling between processing elements to reflect the possibility that the density of active fibers joining two netlets can be a nonlinear function of netlet activity.

- Compact dynamic attractors possess basins of attraction: Similar inputs converge to the same attractor and distinct inputs converge to distinct attractors.

- Ultrastability, whereby every applied input ends up producing a compact dynamic attractor, is guaranteed by the two properties of state-determined bifurcation and the handing over of control over dynamics

- Dynamic attractors can be viewed as short term memory traces that may be used to drive adaptation and learning.

- Chaotic orbits maybe useful for driving adaptation and learning via a chaos suppressing algorithm (under investigation).

- The exponentially decayed contribution $\varepsilon(n)u_i^s(n)$ of the extrinsic input can be viewed as a "soft" or "fuzzy" initial "condition" that acts to direct the network to a part of its state-space where gradually intrinsic control over dynamics takes over to complete the search for a "matching" (stimulus specific) attractor.

- The form of the nonlinear coupling functions used, enables the controlled injection in the network, through the control (bifurcation) parameters $\mu_i(n)$, of excitation and disorder on the one end (small values of c_{ij}) and inhibition and order on the other end (large values of c_{ij}).

- The architecture and organization of the PCLM net makes it ideally suited for the modeling and study of hierarchical cortical networks, such as thalamo-cortical and cortico-thalamic interactions that are considered central to cognition and perception.

- Computing with diverse attractors. The compact dynamic attractors can combine any level of order and disorder(chaos). This defines a new type of attractor in which the relative levels of order and chaos can be controlled by design or can change depending on a parameter value to introduce a mechanism for attention in PCLM nets.

The above listing indicates that PCLM nets provide a new settings for studying cortical dynamics and the way the brain processes, classifies, and learns to recognize dynamic (spatio-temporal) inputs it receives from sensory organs stimulated by the environment. The insight and knowledge gained from this research will be useful for the design of artificial intelligent systems intended to operate in a dynamic changing environment. This included non-cooperative radar target identification systems which seek to (a) utilize the temporal evolution of target signatures in time to enhance the recognition process and (b) do this in compact efficient hardware.

During the period of this report N. Farhat (PI) presented invited talks on Dynamical Networks at Princeton University and the University of Delaware.

References:

- W. J. Freeman, *Societies of Brains*, LEA Associates Publishers, Hillsdale, NJ, (1995)

- Stan Franklin, *Artificial Minds*, MIT Press, Cambridge, MA, (1995)